The Changing Perception in the Artefacts used in the Design Practice through BIM Adoption

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Abstract

When CAD (Computer Aided Design) was generally adopted in the early 1990's, the hand drawn process was replaced with the CAD drawing but the nature of the artefacts / deliverables and the exchanges of information between disciplines remained fundamentally the same. The deliverables remained 2D representations of 3D forms and Specifications and Bill of Quantities. However, the building industry is under great pressure to provide value for money, sustainable design and construction. This has propelled the adoption of Building Information Modelling (BIM). BIM is a foundational tool for a team based lean design approach. It can enable the intelligent interrogation of design; provide a quicker and cheaper design production; better co-ordination of documentation; more effective change control; less repetition of processes; a better quality constructed product; and improved communication both for the architectural practice and across the supply chain.

As BIM enables a new of working methodology, it entails the change in perceiving artefacts used and deliverables produced in the design and construction stages. In other words, defining what the informational issues are, who does what and who is responsible for what and the level of detail required at each stage in design and construction is critically important to adopt and implement BIM in the construction sector.

This paper presents the key findings through the action research methodology about the change in the nature of artefacts and deliverables resulting from the BIM adoption in the KTP (Knowledge Transfer Partnership) project undertaken by the University of Salford and John McCall Architects.

Keywords; Lean Construction, Building Information Modelling, coordination, collaboration, integrated design process

1. Background: Artefacts used in the building design process

"How complex or simple a structure is depends critically upon the way in which we describe it."
Herbert Simon (1996)

The construction industry is facing a dilemma with a demand to simultaneously reducing costs, increasing quality and improving efficiency. The challenge is how to meet this demand for improvement.

Historically information within the building process has been fragmented, unconnected and characterized by sub-optimal informational exchange. Yet the building design process has a disproportionate influence on the life cycle value of the built environment (Paulson 1976). So optimal design and the intermediate stages by which good design is achieved are particularly important.

Within the construction industry there are many disciplines or communities of practice. Each community has its own area of specialist knowledge. Artefacts are the method adopted to transfer information and ideas between these communities. (Lave and Wenger, 1991)

When the effectiveness of artefacts (boundary objects) is considered from a lean perspective, any waste residing in or in the production of the said artefacts should be removed. This waste in lean terms could be over-processing, rework, overproduction, conveyancing, waiting, inventory or motion.

Artefacts of the building process are the intermediate creations required to ensure that intermediate and final building project requirements are met. The components that go to make up an artefact are prescribed by the importance given to quality, cost and time considerations. The format of the artefact is often prescribed by legacy systems, historic methods and practices. According to Cooper (1989) in each period of our history, design and communication have evolved synchronously with the technology of the time. Each new medium has extended our sense of reality and each has looked to its predecessor for language and conventions, referencing and adapting characteristics until its unique capabilities can be explored and codified.

2. The Case Study Company: John McCall's Architects (JMA)

JMA was established in 1991 in Liverpool in the UK, and has been involved in architecture and construction for almost 20 years designing buildings throughout Northwest England. Focusing primarily on social housing and regeneration, the company is known for good quality, economical, environmentally sustainable design. JMA works with many stakeholders from the design through to building construction process and the associated information is very fragmented. Projects in which JMA are involved are typically of 2½ years duration, involving many stakeholders and requiring considerable interoperability of documentation and dynamic information.

2.1 Knowledge Transfer Partnership Project with JMA

The specific academic challenge of the KTP is to link BIM implementation with Lean process improvements. The KTP project aims not only to implement BIM and therefore assess the degree of the successful implementation, but rather to position this within the context of value-add offerings that can help the company place itself at the high-end knowledge-based terrain of the sector. The KTP adopts a socio-technical view of BIM implementation in that it does not only consider the implementation of technology but also considers the socio-cultural environment that provides the context for its implementation. Within this context change management and adoption strategies will be a challenge.

BIM has actually been utilized by large architectural practices and on large building projects e.g. London Underground, but it is not widely (if at all) used by SMEs. The KTP will enable JMA to establish itself as the vanguard of BIM application giving them a competitive edge because BIM can enable the intelligent interrogation of designs; provide a quicker and cheaper design production; better co-ordination of documentation; more effective change control; less repetition of processes; a better quality constructed product; and improved communication both for JMA and across the supply chain.

The impact of the KTP will be also to improve the process at every level and stage: eliminating the risk of miscalculation, misinterpretation of design, improve communication, provide interoperability between stakeholders and, ensuring control and sharing of documentation. This is because BIM is a foundational tool for implementing an efficient process and invariably leads to lean-orientated, team based approach to design and construction therefore BIM will allow JMA to demonstrate the entire building life cycle including the construction and facility operation during the design phase.

3. Research Methodology

A soft system methodology to improve the shared understanding of the existing architectural practice in JMA was employed as the method of research. This is achieved by making models in order to diagnosis and vision the working process. The contextual design approach was adopted to find out how the members of staff carried out their activities at JMA and identify the correct needs and user requirements through contextual inquiry. This was undertaken by a series of interviews of members of staff in their working situation.

Artifact models have been generated based on the syntaxes prescribed in the contextual design approach in order for the diagnosis of the current practice in regard to the artifacts in use. This is then followed by the storyboarding technique to pictorially describe and model the artifacts to be used in BIM implementation. Flowcharts and diagrams were produced for the artifacts modeling.

3.1 The properties of the Artefacts (in JMA's Design Practice)

Artefacts created and used at JMA include models, sketches, drawings, specifications, bills of quantities, outline and full planning submission documentation, building control submissions, CDM submissions, contracts, program and construction plans of work and as built documentation. The specific artefacts required depend on the method of procurement. Artefacts are often used as milestones and are often used as approval points on projects.

The format and contents of the artefacts produced is generally determined by recipients and the client. Sometimes the formats are prescribed at the outset in the terms of agreement. In order to change the deliverables, discussions with the recipient and confirmation of the validity of new artefact formats need to take place. Construction projects are typically information-intensive collaborations between diverse collections of stakeholders and organisations. Contributions to the artefacts may be created by different disciplines within the building process. But they are often integrated into a single combined artefact by the project architect.

Artefacts are defined by the following properties:

a) <u>Physical or virtual form</u>: An artefact can exist in both a physical and/or virtual form. Examples of physical artefacts could be printed drawings or construction mock-ups. Examples of electronic artefacts could be files in many formats for example dwg, dgn, skp, pdf, etc.
b) <u>Shelf Life and time of influence</u>: Artefacts have a shelf life. It is appropriate to use artefact for a certain length of time after which it is necessary to confirm whether the artefact and the information in the artefact has been superseded. If obsolete artefacts are used, abortive work or unforeseen problems may arise.
c) <u>Accuracy</u>: Many developers worry about whether their artefacts -- such as models**,** images, or documents -- are detailed enough. The accuracy required depends on the intended use. Accuracy can be measured against any property and how correctly it reflects the condition in the real world. However, it is more appropriate to measure accuracy against the fit for purpose. This raises the issue that information that is sufficient for one purpose may not be sufficient for another purpose. For example, it may not be necessary to have artefacts accurate to the nearest millimetre for outline planning whereas it may be necessary for construction.
d) <u>Objectiveness (addressing an issue) and the fit for purpose</u>: An example of an artefact meeting an issue would be information submitted to achieve building control approval or planning permission. An example of an artefact created to achieve a milestone would be an approved preliminary design report. How well an artefact achieves its objective is a measure of its effectiveness. Artefacts may address one or many objectives.
e) <u>Creator or Developer</u>: All artefacts have a creator or developer and this is as likely to be a team of people as it is to be an individual. It is usually the case that artefacts are constructed using constructs or acquired earlier in the development process. Where constructs are used the artefact is developed as opposed to being created. If the processes change, who the creator or developer of a particular artefact may also change.
f) <u>Perceived recipient and method of communication</u>: Every design-construction problem can be represented in multiple ways. The clarity and comprehensibility of intent and meaning in the

artefact is a function of human perception and interpretation. Artefacts are required to generated a common shared understand about the project related issues. These are issue of organisational semiotics. Organisational semiotics (OS) is the study of sign generation, exchange and interpretation in organisational contexts. Artefacts may be generated not only for human validation but also for machine based checking. Particular artefacts are designed to be communicated in particular ways.

g) Codes and Standards: the design artefacts that are prepared to discuss the scheme with the users are constrained by project factors; timescales and the conventions adopted by a practice. For example, planning applications is a good example of an artefact prescribed by legislation. The Town and Country Planning (General Development Procedure) Order 1995 sets out a statutory list of information that is required to accompany planning submissions. The standardisation of artefacts is to some extent understandable because at times it is necessary to compare and contrast artefacts.

h) Ease of creation: One facet of an artefact is how easy it is to construct. This is particularly relevant in the business area where cost competition exists.

i) Responsibility: Where an artefact is created to meet a specific purpose, someone or a group of people will be assigned with the related responsibility associated with the artefact.

j) Stepping stone: Building process artefacts are effectively stepping stone in the building process. As such they are tailored to a specific objective.

k) Standalone Value: Artefacts often have a value in themselves even though they are a stepping stone to something else. For instance, a building model that is to show the design to a prospective owner may have a value in itself.

l) Static and responsive artefacts: Some artefacts remain in a static state while others are responsive to external changes. An example of a responsive artefact would be a model with solar louvers that respond to daylight levels. As computerised models become more widely used more responsive and interactive artefacts are likely to be developed.

m) Orphaned or connected: sometimes an artefact is an orphan and sometimes it remains connected to its source.

3.2 Changes in Artefacts via BIM Adoption and Implementation

The use of Building Information Modelling and the associated changes in the nature of the artefacts produced are bringing about changes the construction industry. In the new way of working a methodology that is brought in by BIM, it would be wrong to consider artefacts as individual entities rather as data models. From this model information is extracted and filtered to provide artefacts of the appropriate level of detail for their purpose. Often the additional textual or graphical overlays are added. The elaboration of these artefacts is carried out in four steps:

- Step 1: the elaboration of the artefacts that are created to develop and understand the design solution,
- Step 2: the elaboration of the artefacts that are created to achieve approval of designs
- Step 3: the elaboration of the artefacts that are created to facilitate construction and
- Step 4: the elaboration of the artefact so-called “single lifecycle building model”.

3.3 Artefacts for Design Development and its Understanding

The analysis of spoken interaction between architects and users in the early stages of a building's design has revealed that artefacts serve a dual purpose. Artefacts embody the current status of the design and to act as mediating devices to develop an understanding of the design in conversation (Luck 2007). Traditionally during the design development the information moves from one point of stasis to another. During to intervening periods the information may be in an inconsistent unresolved form. Knowledge is developed not so much through relatively stable boundary objects (artefacts) but through constantly unfolding epistemic objects (Ewenstein 2009). Epistemic objects are objects abstract in nature, they are objects of inquiry and pursuit. During this stage there is a development through iterative design cycles from the fuzzy conceptual ideas to the geometric representations.

Evidence suggests that architects as a group cannot predict the public's aesthetic evaluations of architecture (Brown & Gifford, 2001). Many research projects in environmental psychology have revealed that architects and non-architects perceive architecture differently (Devlin, 1990; Hubbard, 1996; Gifford, 2002.) This means that the creation of artefacts is particularly important to transfer ideas and concepts in order to establish a good communication and shared understanding amongst the stakeholders and users of a project.

Traditionally design representations fail often to articulate the future experience of a space to clients and stakeholders. Individual drawing which are the legacy artefact of the building process have no value other than in a printed form. Traditional CAD systems have assisted in the production of such representations but the inherent intelligence of the information contained is minimal. BIM enables the use of three-dimensional virtualization of buildings with additional information on demand in a way which is impossible using two dimensional ideas and concepts on paper.

The type of representations used has to be tailored to the awareness of the clients. The correct approvals can only be solicited if first a correct understanding is transferred to the person responsible for approval. This is partly to do with organizational semiotics and also partly to do with the mechanism of information transfer. Drawings presented to clients may sometimes look impressive but are in fact symbolic artefacts and they conveying actual information poorly. Such symbolic artefacts are sometimes referred to as illuminated scrolls because the embellishments overlaid do nothing to enhance understanding of the content. As an artefact for further development, illuminated scrolls traditionally have been considered as not maintainable due to the diligence it requires to preserve the symbolic quality. With the uses of BIM less informational atrophy needs occur during the development cycle.

BIM is one solution to enabling shared understanding and successful communication for effective design development. This is achieved by the creation of virtual preconstruction models so that the client or recipient can drive the direction of his or her design interrogation. This means that the design review is not prescribed with predetermined images and views taken from preset perspectives. As a result, the traditional artefact is replaced by a more effective virtual artefact. Although the initial role of the virtual artefact is to explain, ultimately the role of the artefact should initiate meaningful dialogue and interaction.

3.4 Artefacts developed to gain approval

Examples of artefacts created for pre approval are planning and building control submissions, costing and other criteria prior to the commencement of construction. With the change from man to machine validation, the nature of the artefact will change through the implementation of BIM. For example, Rule checker software has achieved increased interest and is often regarded as one of the big benefits by using BIM/IFC based software in the design process. When new BIM based artefacts are used, it is necessary for them to have equivalent contractual and legal status as the traditional artefact. The CORENET system in Singapore represents a an advanced development that is an Automated Code Checking system based on intelligent IFC2x objects, which allows automated approval of building plans over the Internet. Developments in the UK may also occur along the same lines.

3.5 Artefacts developed to facilitate construction

Architects create constructs of what is to be built; contractors then deconstruct these in elements and associated activities. By creating artefacts that can be deconstructed and undergo analysis BIM can be used to facilitate the construction process. The object orientated approach of BIM has the ability to separate the building by element which in turn facilitates breaking down the production information into smaller work packages.

Earlier involvement of the contractor can enhance the design process. But in a traditional contract process, contractor involvement only occurs at tender stage shortly before construction starts on site. This means that the knowledge from the contractor for constructability is not feed into the early stages of design development. A package approach can also be used to facilitate CAD/CAM and site manufacture. Particularly when working with elemental building packages being able to undertake clash detection and deviations becomes an important issue.

3.6 The concept of the lifecycle model

BIM as a lifecycle evaluation concept seeks to integrate processes throughout the entire lifecycle of a construction project. The focus for the stakeholders is to create and reuse consistent digital information throughout the lifecycle (Figure 1). BIM incorporates a methodology based around the notion of collaboration between stakeholders using ICT to exchange valuable information throughout the lifecycle. Such collaboration via use of BIM artefacts is seen as the answer to the fragmentation that exists within the building industry (Jordani, 2008).

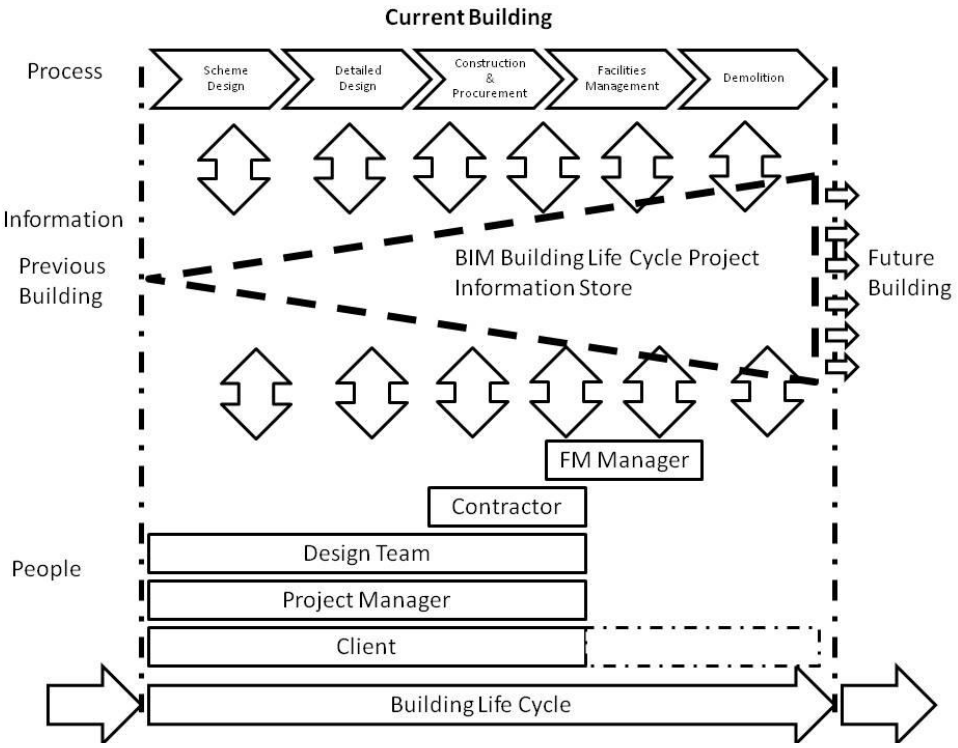

Figure 1: The BIM Lifecycle of information

3.7 The Artefacts in JMA's BIM Enabled Design Process

The table below concisely considers the ongoing changes in the artifacts used in JMA's Design Process via BIM adoption.

Stages in the Design Process	***Non BIM Artefact***	***BIM Artefact***	***Intelligent BIM Artefact***
Feasibility Report	*Hand sketches, basic costing from areas.*	*Massing Model, basic costing generated from the model*	*Bidirectional model and costing information with decision support system*
Preliminary Sketch Design	*Sketch-up model, material lists and costing from areas*	*3d database, with areas volumes and materials and costs*	*Multidiscipline collaborative models with intelligent feedback*
Final Sketch Design	*Sketch-up model and plans in powerdraft, material list and costing from areas*	*3d database, with areas volumes and materials and costs*	*Multidiscipline collaborative models with intelligent feedback*
Planning Design	*CAD drawings created from 2d representations, materials noted on drawings*	*3d database, with areas volumes and materials and costs, with non required information removed, planning specific info added*	*Models that can be placed in context allowing review in virtual reality*
Detailed Design	*Plans, sections, elevations and details produced as 2d*	*3d database – details extracted and worked up*	*Links to product information databases and supplied*

	representations and outline specification, colours, finishes and build ability	*in 2d, schedules generated direct from the database*	*specification and direction. Link to sustainability database and design for manufacture considerations*
Production Information	*Plans, sections, elevations and details produced as 2d representations and full specification, full details*	*3d database, all representation connected reducing inconsistencies, automated BOM*	*3d database – all information in 3d, shop drawings generated direct from the model, construction support system*
Construction Documentation	*Plans, sections, elevations and details produced as 2d representations and full specification, full details and shop drawings and construction sequence drawings*	*3d database usable by the contactor with possible automated manufacture*	*Models indicating sequence of construction, and method of construction*
As Built Drawings – Life Cycle Info	*2d representations of what has been built*	*3d database of what has been built, suitable for facilities management*	*Intelligent identifiable objects with attached maintenance information*

Table 1: the changes in the artefacts used in JMA's Design Process

3.7.1 Feasibility Report

Feasibility has not been a major focus in the development of BIM systems. In JMA's case and generally feasibility is undertaken to acquire project funding. To achieve funding schemes need to achieve a certain level on the housing quality index. There are ten indicators that measure quality. Each indicator contains a series of questions that are completed by the applicant organization. Indicators concerning the site are visual impact, layout and landscaping, open space and routes and movement. Indicators concerning the units are size, layout, noise, light, services and adaptability, accessibility within the unit, sustainability and building for life. Though the use of BIM these factors can more easily be investigated potentially leading on to the development of rule based systems in this area.

3.7.2. Preliminary Sketch Design

The objective of the preliminary sketch design is to validate the design against the brief, scales of accommodation, site constraints, target costs and to determine the main issues related to construction and engineering. In the preliminary stage of the design the issues and road blocks for the design are researched and evaluated. Using BIM massing models the level of detail can be increased and alternative options explored. The particular benefit of BIM at this stage is the ability to undertake rapid prototyping to find the optimal solution meeting the requirements of the brief.

3.7.3. Final Sketch Design and Planning Submissions

The final sketch design is to confirm the final form, appearance, construction method, services installations, landscaping, roads, car parking and construction phasing. This information should be sufficient in order to make a planning application. The objective from the client's perspective of making planning applications is to gain planning approval. Yet at the same time not restricting possible further design development which might be beneficial to the client. By appropriate filtering of design information using BIM these combined objectives can be achieved. The means it is not necessary to develop a data set purely for planning application purposes.

3.7.4. Detailed Design and Production Information

The objective of this stage is to integrate detail design decisions of all disciplines into a unified scheme and to obtain all the necessary approvals. Building control submissions are usually made as part of this stage. The traditional problem with construction documentation is clashes between disciplines. The ducts clash with the structure etc. With the use of combined models clash detection can be undertaken both construction. This represents a major gain in the process.

But the question is how can the tradition production information offering be improved? The consistency of representations generated from a single model avoids many discrepancies that occur using traditional methods. With the structuring of elements in BIM the production of elemental work packages becomes easier. Also because objects are used substitution of elements also becomes easier.

3.7.8 As Built Drawings-Lifecycle Information

As built information is the cornerstone of effective facilities management. With the use of IFC models JMA has the potential to provide a more sophisticated form of as built information. Discussions with clients are currently taking place to develop better artefacts in this area.

4 Conclusion

New artefacts are emerging. At JMA a proactive approach is being taken to discover more effective methods of conveying building design information and concepts. Yet artefacts fall short in their ability to fulfil what is required. In the construction or creation of an artefact there is an inevitable trade off between the ease of creation of the artefact and how effectively it conveys its message to its recipients. Using IFC compatible objects as the building blocks for artefacts in the design process has the potential to facilitate and add value to the work of both the recipient and the creator. By creating more intelligent boundary objects specialist knowledge can more easily be shared. Major benefits to the contractor and end user can be realized with intelligent objects being used to construct the artefacts of the building process. To improve the ability of BIM to communicate the correct messages common BIM standards need to be adopted by all stakeholders in the building process and working practices also need to change.

With the adoption of BIM it is easy to focus on 3d building representations when other forms of representation should be considered. The form of representation could be a pie chart, a venn diagram, a flowchart or a synergy diagram the most appropriate form should be adopted. Building Information Modelling (BIM) offers a new way of documenting, designing and streamlining the building lifecycle processes. Therefore, with the move towards BIM, it is more realistic to envisage a holistic building model which promises a way of working that gives speed, efficiency and clarity to the construction process.

Finally, we must not lose sight of the fact that the end goal is a building that meets it requirements on all levels. Efficiency in design process and construction are merely the method to facilitate this end objective.

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